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MASTER

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NEUTRON SPECTRUM AT 90° FROM 800 MEV (p,n) REACTIONS ON A Ta TARGET

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The neutron time-of-flight spectrum produced by a thick tantalum target bombarded by 800-MeV protons has been measured at an angle of 90°. The data were taken at the Weapons Neutron Research facility using a cylindrical Ta target with a radius of 1.27 cm and a length of 15 cm. An NE-213 liquid scintillator was used to detect the neutrons over an energy range of 0.5-350 MeV. The neutron yield is presented and compared to a intranuclear-cascade/evaporation model prediction.

[Ta(p,xn), Neutron Yield, 800-MeV Protons, 0.5-350 MeV Neutrons, Intranuclear Cascade Predictions]

Introduction

The Weapons Neutron Research facility (WNR)[1] is a pulsed spallation neutron source operating at the Los Alamos Scientific Laboratory (LASL). The neutron energy spectrum produced by the WNR target has not been well characterized experimentally. Until now, theoretical predictions by a Monte Carlo intranuclear-cascade/evaporation code, NMTC,[2] have been used to represent the expected distribution. In this paper the results of a measurement of the neutron yield from the WNR Ta target are given for energies between 0.5 MeV and 350 MeV. A comparison of the data to a theoretical prediction is also made.

Experiment

A brief description of the WNR is presented here since previous papers[1,3] have given complete details. Up to 1% of the 800-MeV proton beam from the Clinton P. Anderson Meson Physics Facility (LAMPF) is transported to the water-cooled Ta target at the WNR. The target is 2.54-cm diam by 15-cm long. For this measurement, the proton beam consisted of micropulses less than 200 ps wide separated by 11 μs and occurring over intervals of 640 μs. The beam intervals were repeated at 12 Hz.

Collimated and evacuated flight paths perpendicular to the incident proton beam provide neutron beams to outlying detector stations. The experimental arrangement used in this measurement is shown in Fig. 1. The collimators in the shield surrounding the target consisted of two sets of movable copper jaws. These collimators limited the neutron flux to a 2.5 cm spot at the edge of the shield. In conjunction with a third collimator located outside the shield, a 0.95 cm diameter neutron beam was formed and passed through a sweep magnet to remove charged particles. This collimator combination limited the acceptance of the detector to a 2.5 cm square area of the target centered approximately 3.2 cm below the top.

The neutron detector used was a 5.1-cm diam. by 2.5-cm thick NE-213 liquid scintillator located 29.37 meters from the Ta target. The detector bias was set using the 60 keV gamma ray from an ^{241}Am source. This established the neutron energy bias at approximately 425 keV. The efficiency of the detector at this bias was measured up to 31 MeV at the LASL Tandem Van de Graaff accelerator. From 31 MeV to 800 MeV the efficiency was calculated using a Monte Carlo neutron efficiency code.[4,5] The measured detector efficiency and the Monte Carlo calculation are shown in Fig. 2. The calculated efficiency is about 15% higher than the measured value. This discrepancy indicates that the detector efficiency must be experimentally determined above 31 MeV. Work is presently underway on this problem.

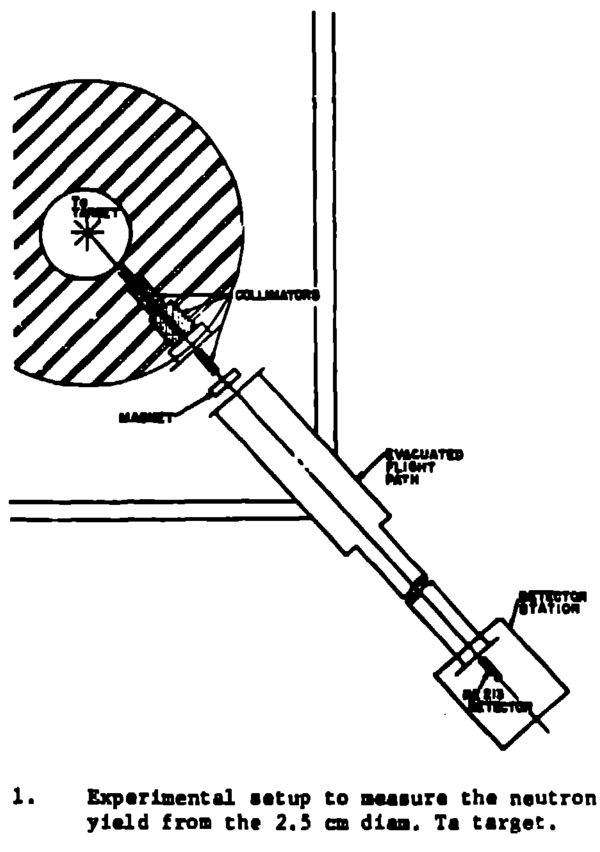

Fig. 1. Experimental setup to measure the neutron yield from the 2.5 cm diam. Ta target.

[*]Work performed under the auspices of the U.S. Department of Energy.

Electronics

A constant fraction timing discriminator was used to establish the neutron detection threshold and to provide stop signals for an EG&G TDC-100 clock. The clock was operated in a single stop per start mode at 0.5 ns per channel and with a 4 μs dead time. The start signal for the clock was provided by a capacitive pickoff positioned in the proton beam line. The signal generated by this pickoff was amplified and fanned out into two equal signals. One of the signals went to a ORTEC TDC-200 fast trigger whose output started the clock. The output of the clock was then stored in a MODCOMP IV computer. The count rate for this measurement was sufficiently low that the computer dead time was negligible.

The other pickoff signal was used to determine the number of protons incident on the target as follows. The signal was integrated and passed to an ORTEC QD808 charge digitizer. The digitizer, which has a conversion time of ≤ 6 μs, provided a pulse height distribution related to the number of protons in each pulse. The relationship between this spectrum and the number of protons, p, is given in Eq. (1).

$$p = K\beta\left[\frac{\sum_i C_i X_i}{\sum_i C_i} - A\right]\text{(protons)} \quad (1)$$

where C_i is the number of counts in channel X_i, β is the number of clock busy signals, A is the pedestal channel number of the QD808, and K is the constant of proportionality. The value of K was determined by bombarding a set of Aℓ foils with proton micropulses and simultaneously digitizing the pickoff signal using the QD808. By counting the gamma rays of the ^{24}Na, ^{22}Na and ^{7}Be spallation products, the number of incident protons was determined. Two such foil activations were made for this experiment explicity determining both K and A.

Data Reduction

The calculation of neutron yield first involved converting from time-of-flight to energy. This was done relativisitcally. The data were binned so that the energy resolution, $\Delta E/E$, was constant and equaled

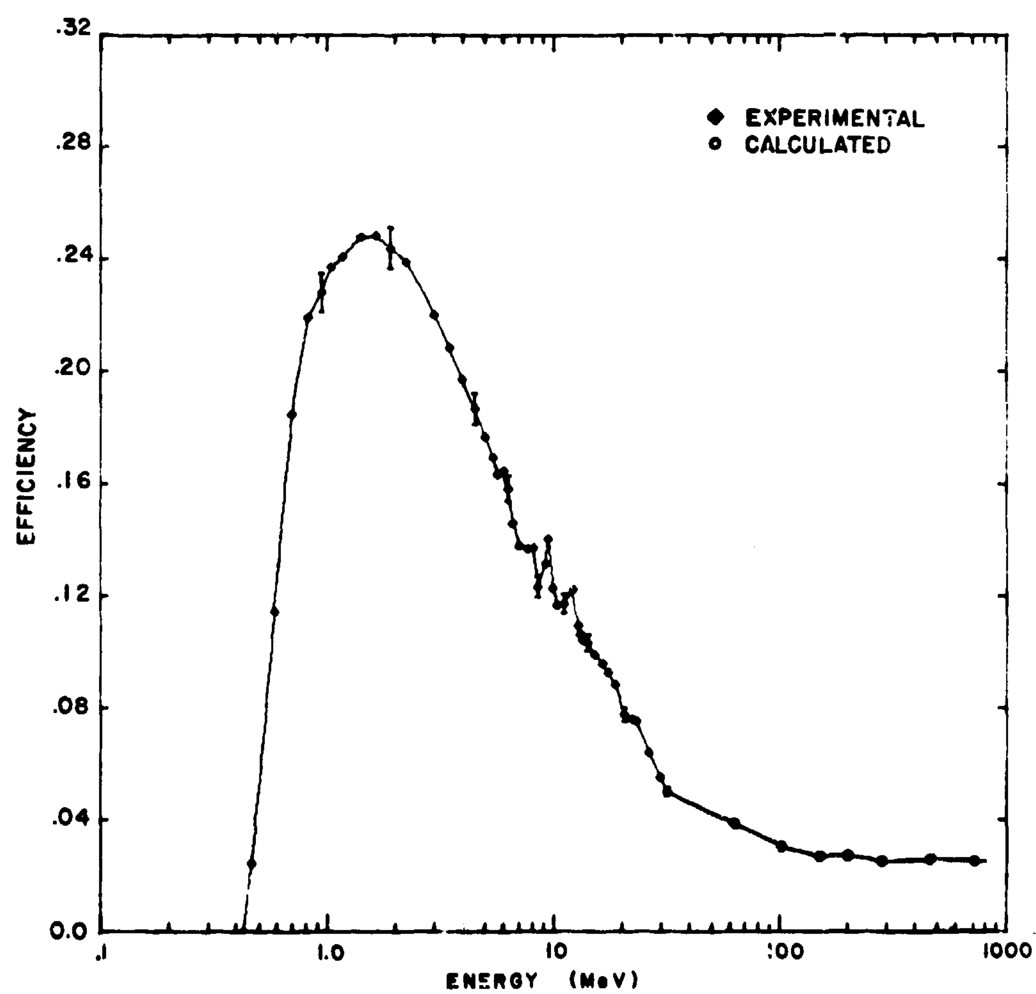

Fig. 2. Efficiency of the NE-123 neutron detector for a 0.43 MeV neutron energy bias. The values above 31 MeV were calculated using a Monte Carlo code. The solid line is a guide to the eye.

0.05. The actual time resolution of the experiment was 42 ps/m as determined from the gamma flash time width.

The neutron yield, Y(E), in energy interval ΔE about energy E is found from:

$$Y(E) = \frac{R(E)}{p\Delta\Omega \quad \varepsilon(E)} \quad (n/p\cdot sr\cdot MeV) \tag{3}$$

where R(E) represents the number of events in ΔE corrected for clock dead time losses[6], p is the incident number of protons, $\Delta\Omega$ is the solid angle subtended by the detector, and $\varepsilon(E)$ is the efficiency of the detector at energy E averaged over ΔE. The solid angle was calculated by a Monte Carlo code.

Statistical errors in this measurement varied from less than 3% around 1 MeV to 5% above 100 MeV. The sources of systematic error include determination of the incident number of protons, calculation of the solid angle, transparency of the collimators to neutrons with energy greater than 100 MeV, and estimation of the neutron detector efficiency above 31 MeV. The magnitude of the systematic errors is estimated to vary from 11% for En $\leq$ 30 MeV to 13% at higher energies. More effort is being made to understand these errors and include their effects.

Results

The experimental results are shown in Fig. 3 and compared with a calculated prediction using the computer code NMTC. The error bars on the experimental data are statistical only. The main features shown by this initial comparison are the low calculated neutron yields at both high and low energies. The two spectra do agree in the energy region around 10 MeV.

The underprediction of the calculations above $\sim$ 50 MeV is consistent with other results[7] obtained using 740-MeV protons but disagrees with 450-MeV proton data.[8] The disagreement at energies below $\sim$ 5 MeV could be due to: a) parameters used in the evaporation model, b) instability in detector bias, c) the inability to calculate proton transport below 20 MeV, and d) use of an outdated neutron cross section library below 20 MeV. The computations are being repeated with more

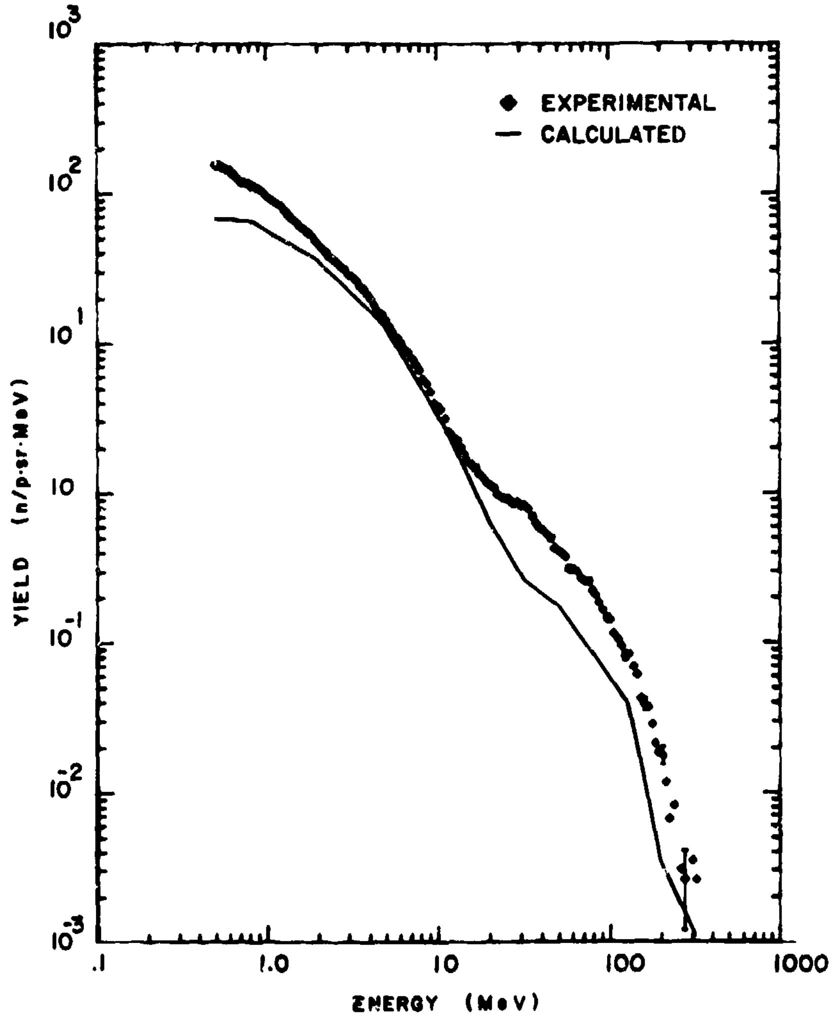

Fig. 3. Neutron yield for the 2.5-cm-diam by 15-cm-long Ta target at the WNR. The solid line was calculated using the Monte Carlo code NMTC. Statistical errors of the data below 100 MeV are represented by the dot size. Typical error bars for data above 100 MeV are shown.

stringent requirements on solid angle and energy resolution binning and using the latest ENDF-B cross sections.

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